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circle. At the starting position shown by the dotted circle the point B was at A and the radius DB was in the position CA. Since arc AE = arc BE and the circles have equal radii, angle AOD = angle ODB. Also, $DB = \frac{1}{2}OD$. These two equalities are fundamental in the construction of the linkage.

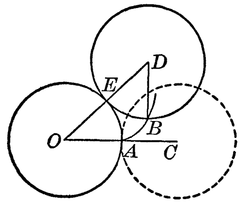

FIG. 1.

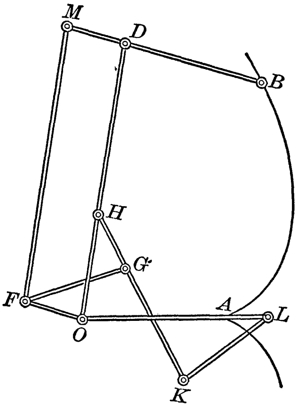

FIG. 2.

The links, BM, MF, DO, FG, HK, KL, OL, OF, are pinned together at D, M, F, G, H, K, L, and O, so that $OD = 2DB$; $DM = OF = HG$; $FM = OD$; $FG = OH = KL$; $HK = OL$; and $OH : HK = HG : OH$ (Fig. 2).

From the similar triangles OHK, OLK, OHG, and OFG, we have angle HOL = angle HOF.[1] In the parallelogram $OFMD$, angle FOD = angle ODB, i. e., angle AOD = angle ODB.

Hence, if the part OL is kept fixed the linkage compels the point B to move according to the two equalities derived from the definition of the cardioid, and a pencil fastened at B will describe a cardioid if OL is kept fixed while the other parts are free to move.

BOOK REVIEWS.

EDITED BY W. H. BUSSEY, University of Minnesota.

One Thousand Exercises in Plane and Spherical Trigonometry. By EDWIN S. CRAWLEY. Published by E. S. CRAWLEY, University of Pennsylvania, Philadelphia, Pa., 1914, v+70 pages. $0.50.

Professor Crawley, who is the author of a text-book on trigonometry, has recently published this book of exercises to be used with any text-book. The exercises are intended for class-room drill, and are therefore for the most part of an average grade of difficulty. The first 950 exercises are arranged in a classified list as follows: The measurement of angles (Ex. 1–25); The functions of one angle (Ex. 26–125); Plane right triangles (Ex. 126–150); Problems involving the solution of plane right triangles (Ex. 151–305); Identities involving more than one angle. Inverse functions, etc. (Ex. 306–525); Plane oblique triangles (Ex. 526–550); Problems involving the solution of plane oblique triangles (Ex. 551–625); Problems involving areas, altitudes, etc., of triangles, and the radii of circles related to a triangle (Ex. 626–700); Trigonometric equations (Ex. 701–800); Spherical right triangles, and quadrantal triangles, and applications (Ex. 801–870); Formulas of spherical triangles (Ex. 871–900); Spherical oblique triangles and applications (Ex. 901–950).

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[1] On the theory of linkages in general consult Arnold Emch: "Kinematische Gelenksysteme und die durch sie erzeugten geometrischen Transformationen," Solothurn, 1907.

Exercises 950–1,000 are of a miscellaneous character. Answers to all the exercises are given at the end of the book.

W. H. Bussey.

The Theory of Numbers. By R. D. Carmichael. John Wiley & Sons, New York, 1914. 94 pages. \$1.00.

This little volume (No. 13 of the "Mathematical Monographs" edited by M. Merriman and R. L. Woodward) contains in the first seventy-five pages an excellent introduction to the classical multiplicative theory of numbers, while an additional chapter of seventeen pages gives a brief account of the meaning of some advanced topics, such as Fermat's Last Theorem, Theory of Quadratic Residues and Galois' Imaginaries, all of which are too technical for a detailed treatment in a short introductory book.

The volume would seem to the reviewer to be particularly valuable for self-study. Any reader who will thoroughly master it will have gained a clear idea of the fundamental questions of the theory, and will be well prepared for the study of more complete or more advanced treatises.

A valuable feature is the list of 84 problems which are distributed among the various chapters. Many of these are of interest in themselves, and their careful study will do much to make the abstract theory gain a concrete meaning.

The titles of the chapters will serve to indicate the subjects treated:

(1) Elementary properties of integers. (2) On the indicator of an integer. (3) Elementary properties of congruences. (4) The theorems of Fermat and Wilson. (5) Primitive roots modulo m. (6) Other topics.

The last chapter is the only one where references are given. Although the first five chapters are quite self-contained, an occasional reference would be useful, even to readers familiar with the subject. For example, the proof of Wilson's theorem, as given on p. 50, while it may be well known, is new to the reviewer. On pages 50–51 it might well be stated in connection with Wilson's theorem (although commonly omitted in books on number-theory) that the trivial congruences:

$$(n-1)! \not\equiv 0 \text{ mod. } n, \text{ for } n \text{ prime,}$$

$$(n-1)! \equiv 0 \text{ mod. } n, \text{ for } n \text{ not prime, } n > 4,$$

furnish also a complete test for prime numbers.